McKinsey & Company

Industrial robotics

Insights into the sector's future growth dynamics

July 2019

Contents

Introduction and key messages

For some time now, there has been talk about how the global industrial robotics market is poised for dynamic growth.[1] With an uptick in robot sales from 2011 to 2018, the buzz around robotics is loud. However, little is known about which specific qualitative factors are informing this growth forecast, and there is uncertainty about what the growth trajectory might look like.

What is known, however, is that the sector has been growing rather steadily since the 1960s. After the first industrial robots appeared in the 1960s, a real growth spurt occurred as automotive OEMs automated their weld shops. We now see a second growth spurt in the 2010s. Underlying this second major growth wave are fundamental changes in the industry and the economic environment: dramatic developments in technology and new applications as well as global (mega) trends of rising labor costs, increasing labor turnover and shortages, and decreasing equipment costs and global competition.

It is against this backdrop of fast-paced technological advancements as well as changes in (labor) cost and demographic trends that McKinsey's Advanced Industries Practice has launched a research effort to:

— Describe the characteristics of the global industrial robotics space and market

— Gain insights into which qualitative factors are informing and driving the current and expected growth dynamics

— Identify key options for unleashing the market's full growth potential and discuss their implications for OEMs and system integrators.

This report draws on our own extensive research and the experience of our McKinsey colleagues as well as public data and insights from interviews with OEMs and other industry experts specifically conducted for this report. It is intended not just for robot end users or those responsible for manufacturing, but it is also relevant to leaders across a variety of functions and areas, including operations, supply chain, process engineering, and services.

In 2018, McKinsey conducted a survey (for an overview of the survey's methodology, see Text box 1 in Chapter 2), with qualitative results that provided important additional insights into the robotic sales forecasts currently available.

This extensive research involving end users reveals that the robotics ecosystem (OEMs and system integrators) can further unleash the adoption of robotics by developing solutions across three main lenses.

Simpler to apply

Potential end users will be increasingly likely to envision use cases for robots as the choice of robots and the talent with the requisite skill set to bring the robots online become more available. Simulation software can further close the gap between conceivability and installation by helping end users prove their design before committing to the final investment.

1 The industrial robotics market is valued at USD 16.2 billion according to IFR, forecasted to grow with a 14% CAGR from 2019 to 2021

Simpler to connect

Readily available industrial connections, simpler integration of end effector, systems I/O, and communication can make robotics easier to implement within existing structures.

Simpler to run

Interactive or interconnected interfaces put even complex programming tasks in the hands of frontline operations, making factories less dependent on expert suppliers and engineering departments.

Additionally, OEMs and system integrators could accelerate the industries' growth by promoting robotics-related upskilling and retraining at scale. OEMs and system integrators can also work to enhance and elucidate the benefits of robotics to small and medium-sized companies, in particular, as a way to help them add this segment to their customer base.

Each of these messages will be explained in more detail in the three chapters that follow.

Outline of the global industrial robotics space

This chapter organizes and takes stock of the current state of the global industrial robotics market and its key characteristics. The resulting overview serves as a backdrop for understanding the driving factors behind the industry's expected growth and how it will come about.

Overview of products and market segments

Unlike the automotive and other machinery industries, McKinsey designates industrial robotics as "low volume, high complexity." The low-volume designation is related to the relatively small number of machines that are produced and deployed within each specification. Two realities characterize the high complexity of the industrial robotics sector: first, the breadth of different machine types that can be included under the umbrella is massive, just in the sheer number of machine types. Second, there is also great variety when it comes to the size, technology, and application areas of robots.

Amid this lack of uniformity or common control systems in the robotics industry, it is important to establish a common understanding of and terminology for the scope covered before analyzing and interpreting both the end users' and sector's perspectives and outlook. For this whitepaper, we have leveraged McKinsey's definitions and categorizations of industrial robots – comprising four subcategories, of which the first is further divided into four segments (see Table 1) – and automation cells and solutions (see Table 2).

Industrial robots

Industrial robots are categorized along the lines of physical attributes (reach, weight, etc.), how they interact with humans, their mobility, and their level of autonomy.

Stand-alone industrial robots

The International Federation of Robotics (IFR) estimates that in 2017, there were around 2.1 million stand-alone industrial robots installed worldwide, with a shipment of 381,000 units globally:[2]

— The largest applications include materials handling operations like machine tending (178,000 units), welding and soldering (82,000 units), and assembling (47,000 units).

— Automotive, i.e., OEMs and, increasingly, automotive suppliers, is the largest industry with 126,000 units, followed by the electrical and electronics industry with 121,000 units.

— China is the largest regional market with 138,000 units. The top five countries (China, South Korea, Japan, Germany, and the US) make up more than 70% of the market.

— In 2017, articulated arms were the majority of industrial robot shipments at 65%, gantry robots were 16%, SCARA robots were 13%, and delta robots represented 1% of shipments.

Stand-alone industrial robots require the presence of safety equipment – such as fences with gates interlocked to the system for safety – and operate exclusively without direct contact with human workers. They are usually fixed (i.e., stationary) and programmed for a specific application.

Collaborative robots

While collaborative robots are still a nascent market with about 10,000 to 20,000 units shipped in 2017, analysts expect strong future growth with more than 100,000 units to be shipped in 2020.[3]

The key difference between collaborative and stand-alone robots is that collaborative robots do not need safety fences for safe operations. Onboard safety mechanisms and a process design that enables collocation and collaboration allow these robots to operate directly and safely alongside human workers. These built-in safety mechanisms reduce the need for external safety measures, such as fencing and interlock for entry, thus reducing installation design costs.

Collaborative robots can be simpler to apply, connect, and run. Quite often, these are single robot installations with simple and discrete input/output interfaces that lower installation and programming costs.

Collaborative robots provide an advantage wherever workers benefit from physical support – for example, by improving process ergonomics and potentially giving older workers or workers with restricted physical ability the assistance they need to be successful in manufacturing. The automotive and electronics sectors are where collaborative robots are currently deployed the most and used not only for incidental work (such as materials handling) but also for value adding (such as assembly). In logistics, however, this robotics category has application in value-added tasks (such as picking) and supportive work (such as kitting and pre-retail services).

Mobile robots

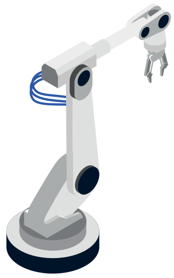
Mobile robots – also known as automated guided vehicles (AGVs) – can be used in a range of applications, including warehouses and distribution centers, manufacturing intralogistics, agriculture, and other environments (especially in logistics in hospitals or retail). There are also first models and prototypes for domestic use. Expectations for AGVs are high. IFR estimates that 69,000 logistics systems had been installed in 2017 (63% of total professional service robot

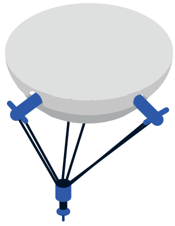
2 Figures for industrial robots include cobots but exclude mobile robots and exoskeletons.

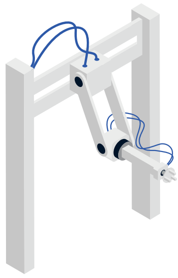
3 ABI Research, Loup Ventures; please note that while cobots are included in IFR's market figures for industrial robots, their share is not listed separately in IFR's market report.

Table 1

Overview of industrial robot segments[4]







Stand-alone – articulated
Articulated robots have rotary joints and between three and six degrees of freedom enabling high flexibility (robot can bend back and forth).

Application
Articulated robots are used for a range of applications, e.g., assembly, painting, arc or spot welding, palletizing, and material handling.

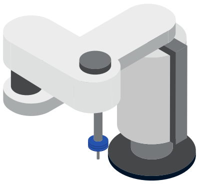
Stand-alone – delta
Delta (also: parallel) robots have three arms that are connected to a base platform via universal joints. Their arms are arranged as parallelograms to restrict the movement of the end platform. Actuators are located at the base platform, so that passive arms can be lightweight and move with great speed.

Application
Applications that require great precision and speed: common applications include packaging, high-precision assembly, and material handling.

Stand-alone –gantry/ linear/Cartesian
Cartesian robots consist of three axes of control that are situated at 90 degree angles of each other. The axes do not rotate but move in straight lines, which simplifies robot control – linear robots are comparably simple.

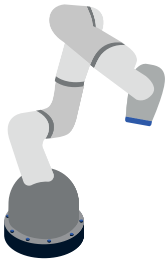
Application
With no need for pedestals, Cartesian robots are useful where space is limited, as they can be mounted overhead.

[4] This overview includes all types of robots used in manufacturing even though some of these are classified as service robots according to other overviews and sources (e.g., IFR).



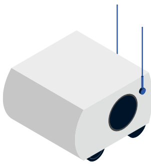
Stand-alone – SCARA
SCARA robots are modelled like human arms with an elbow, shoulder, and wrist. They have three axes for x, y, and z movement and an additional axis for movement of the end effector. The setup of the axes allows the robots to extend their arm and to retract it by folding up.

Application
They are used for fast, repetitive, and precise point-to-point movements, such as palletizing, machine loading, and assembly.



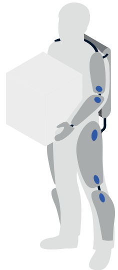
Collaborative
Collaborative robots directly interact with human workers without safety fences and are equipped with machine learning capabilities for easier programming.

Application
They are used to support human workers' strength and precision for certain movements, in processes that require flexibility and reprogramming, or where space is limited.



Autonomous guided vehicles (AGVs) and autonomous mobile robots (AMRs)[5]
AGVs and AMRs are not fixedly installed but mobile. Navigation is either onboard (e.g., camera or laser based) for most advanced types or external (e.g., path based using magnetic tape, wire, or rails on the ground).

Application
Mobile robots are used for logistics and delivery as well as for moving pieces, such as boxes, pallets, or tools, in industrial settings between machinery, transfer points, or storage areas.

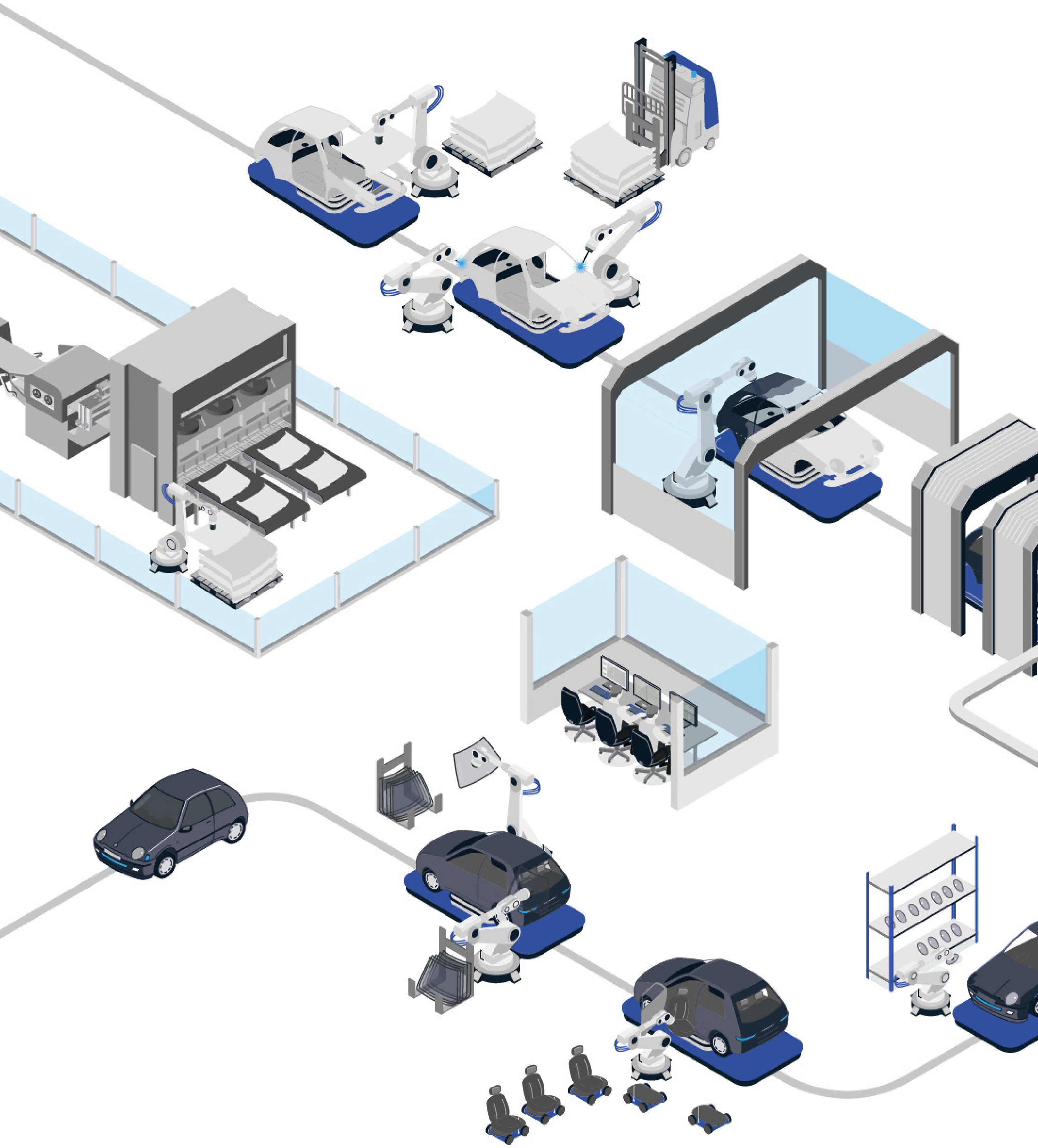


Exoskeletons
Exoskeletons are connected to the human body for support during heavy-duty or ergonomically challenging process steps. They are designed to boost the strength of human workers, e.g., increasing humans' capacity to carry heavy weight.

Application
They can be used in industrial applications to support worker movements (e.g., lifting in warehouses).

[5] AMRs and AGVs look similar but are fundamentally different: both are a type of mobile robots, but whereas AGVs require changes to the infrastructure for guidance (some kind of tracks), AMRs have navigation onboard and require fewer changes to infrastructure.

Table 2
Example of automotive production line



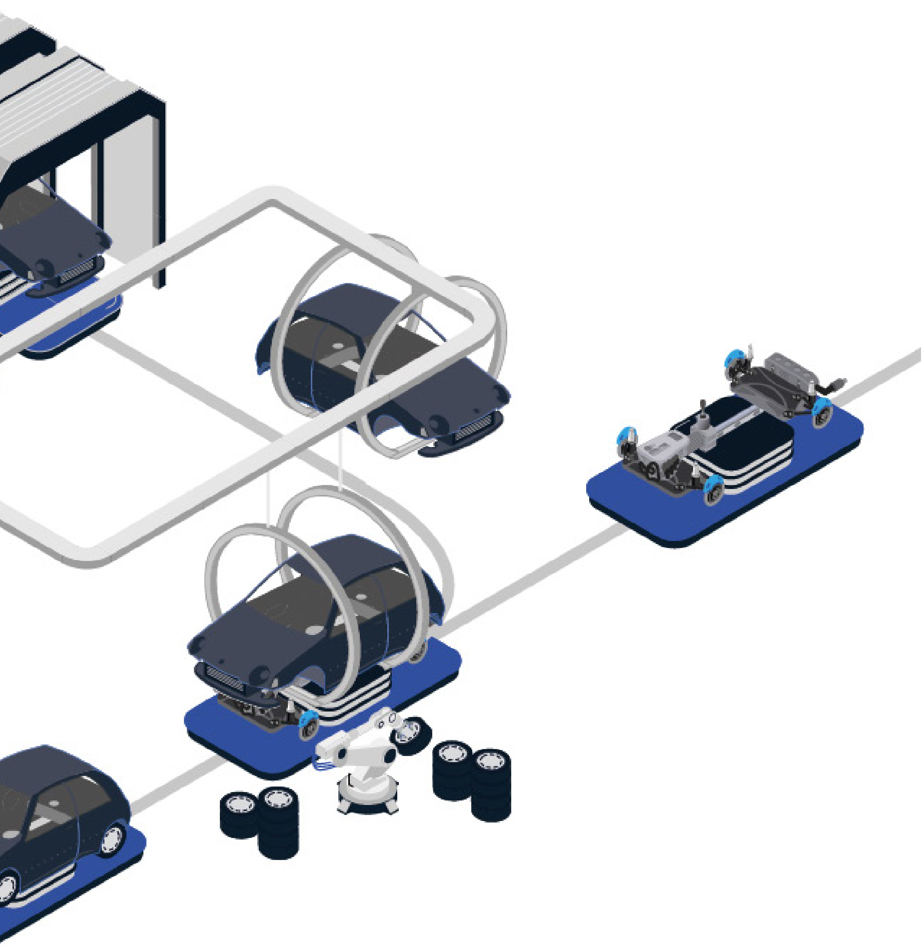
shipments), including around 7,000 AGVs in manufacturing environments. According to IFR,[6] another 600,000 units are estimated to have been shipped by 2021 (for logistics applications both in- and outside of manufacturing). Typically, AGVs are installed in:

— Industrial environments for moving pieces of all kinds (e.g., boxes, pallets, or totes between machinery, transfer points, or storage areas)

— Nonmanufacturing environments, such as warehouses, airports, mail-order postal/parcel logistics centers, hospitals, or other public buildings to transport, deliver, and transfer goods.

Exoskeletons
Exoskeletons, or human-robot hybrids, are robots connected to the human body to support heavy-duty process steps. The idea is to boost humans' strength, increasing their capacity to carry heavy weight. Despite their potential, IFR's estimates for this category are moderate: 6,000 powered human exoskeletons units had been sold as of 2017, and IFR forecasts that only another 48,000 units will have been sold by 2021.

The technology is quite new. Currently, the primary field of applications is rehabilitation. Application areas for use of powered exoskeletons (for lower or upper extremities) have been documented by first demonstrators, and prototypes for other use cases have been tested, e.g., human performance augmentation in defense; rescue and disaster relief; ergonomic support for reducing loads on spine, hips, and shoulders when lifting heavy weights at work, particularly in logistics.



Automation cells and solutions
Industrial robots are used in an increasing variety of structures and are often employed in complete automation systems, which consist of a multitude of industrial robots.

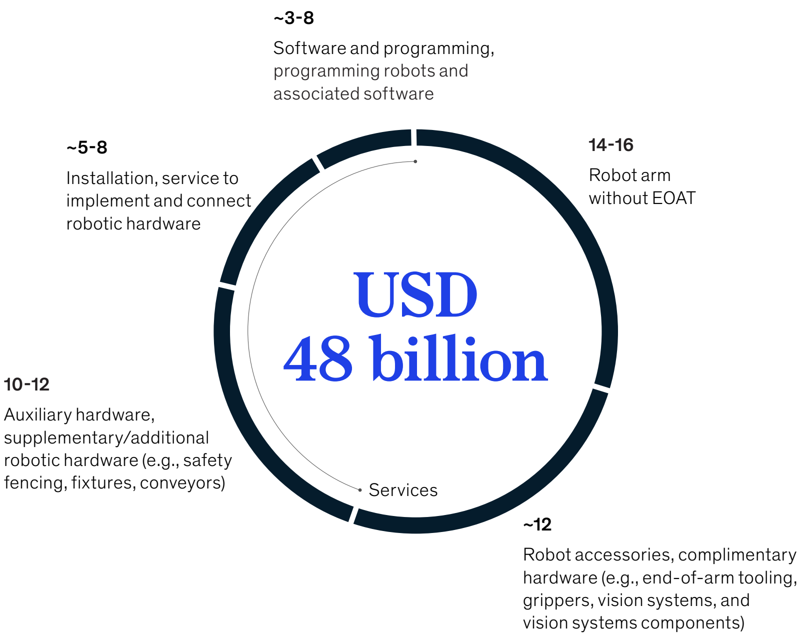
Today, individual robots are applied as a "next step" in automation, for example, for unloading a finished part from a machine tool and afterwards loading a blank part ready for processing. A "second step" in automation are production cells, where a robot has been set up for unloading and loading several machines but was designed as a cell from scratch. These cells are often subsets of full production lines and sold through integrators to the customer. Robotics OEMs offer turnkey cells, including robotic arms, delivery systems such as adhesive dispensers, cell controllers (typically PLC), and safety equipment for specific applications. The aim is to deliver a solution for the end user and reduce complexity for the end customer, who may not have the time or know-how internally. At the same time, increased standardization for the robotics OEM can lower the cost of systems through common solutions. Whether this approach will be successful remains to be seen. Solutions, often highly customer specific, include different robots and cells. Typical examples of automation solutions can be found in automotive (e.g., body in white or paint production lines). Another example is electronics, where production is highly automated and takes place in lights-out, clean-room environments.

6 IFR splits the market into industrial and service robots, the latter including professional and domestic service robots. AGVs and AMRs are included in the service robot report and not in the industrial robot report.

Exhibit 1

Beyond robotics hardware, the total market for robot systems accounts for USD 48 billion

Market breakdown, revenues, 2017, 100% = USD 48 billions



Source: IFR World Robotics; expert interviews

Key facts and figures on the global market

Automation is taking place at scale across industries and countries with relevant technologies evolving or coming into existence. And the expectation is for automation to scale even further worldwide across industries and countries. A recent McKinsey Global Institute (MGI) study[7] has identified significant automation potential across a wide range of industries. Already today, we see that the speed of automation introduction, however, varies between countries.

Robots will become major enablers of automation with large economic impact. IFR estimates that the total market for industrial robotics systems was already USD 48 billion[8] in 2017 (see Exhibit 1). Of this revenue, the robot itself creates about 30% of the revenue, accessories make up about 25%, and service (including auxiliary hardware, software and programing, and installation) the remaining 45%.

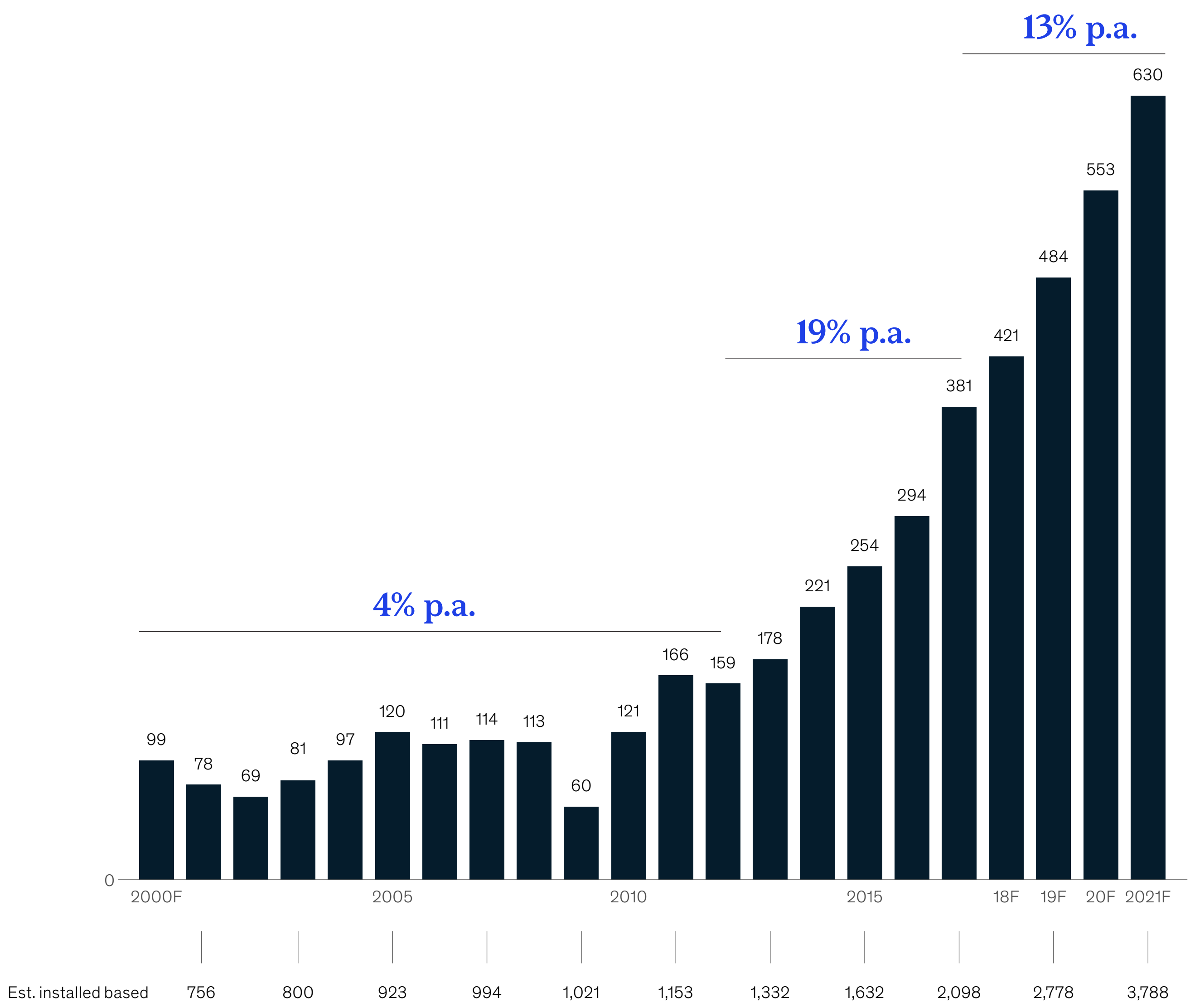
The industrial robotics market experienced record unit sales of 381,000 in 2017 and currently has an installed base of about 2.1 million units worldwide.[9]

7 https://www.mckinsey.com/business-functions/digital-mckinsey/our-insights/where-machines-could-replace-humans-and-where-they-cant-yet
8 Figure includes system integration market for industrial robots. Please note that – in line with what is indicated in Footnotes 2, 3, and 5 – the segments of mobile robots and human-robot hybrids/exoskeletons are reported separately by IFR and are not included here.
9 Source: IFR

Exhibit 2

Annual shipments of industrial robots worldwide

Thousand units



Source: IFR World Robotics; expert interviews

The market for industrial robots has been growing at record rates of around 19% per annum since 2012/13 and is expected to continue double-digit growth at least through to 2021 (see Exhibit 2).[10]

Robotics growth has been driven primarily by the following trends:[11]

Decreasing prices
Smaller, lower-cost robot applications are in high demand. Finally, lower cost of producing robots (e.g., through increasing production in lower-cost regions) leads to decreasing prices (a more than 50% drop in average robotics costs since 1990).

[10] Source: IFR

[11] For further details on these trends, see McKinsey article "Automation, Robotics, and the Factory of the Future," 2017; https://www.mckinsey.com/business-functions/operations/our-insights/automation-robotics-and-the-factory-of-the-future

Increasing variety of models

A larger variety – from the first electrical, 5 axis, microprocessor controlled robot in 1974 to approximately 300 today – enables new applications. What's more, robots have not only become larger and can handle heavier loads (due to an exponential growth of payload from 6 kg to 1,000 kg), but they also feature more axes and require fewer controllers, as in some cases, more than 30 axes can be synchronized by one controller.

Greater technical abilities

Greater precision, for example, enables new applications (e.g., in electronics manufacturing) and safer use (e.g., alongside humans to automate tasks that could previously not be automated). Mobility is another technical advancement, opening the area of intralogistics automation to robotics application.

Increasing labor costs

As the cost of manufacturing labor is rising not just in industrial countries (e.g., 24%[12] rise in manufacturing labor costs in the US since 1990) but also in traditional LCCs such as China or India, the payback for robotics is becoming ever more attractive. The significant rise in labor costs itself is due not only to increasing people/worker and skills shortages but also to an increase in cost-intensive labor transience, as it is no longer uncommon for people to move from job to job.

Accessible talent

While robotics engineers were once rare and expensive specialists, people with the skills required to design, install, operate, and maintain robotic production systems are becoming more widely available.

Ease of integration

Advances in computing power, software development techniques, and networking technologies have made assembling, installing, and maintaining robots faster and less costly than before.

These trends, as well as their impact on the growth of the robotics sector, are expected to continue.

12 Increase in US real hourly compensation (CPI-adjusted dollars per hour worked) for the manufacturing sector between 1990 and 2018; source: US Bureau of Labor Statistics (BLS)

OEMs' and end users' perspectives on the sector's new wave of growth

To gain informed insights into the current and future trends, challenges, and opportunities in robotics and automation (e.g., use cases, types of robots/cells, operator models), we turned directly to the industry's manufacturers and end users.

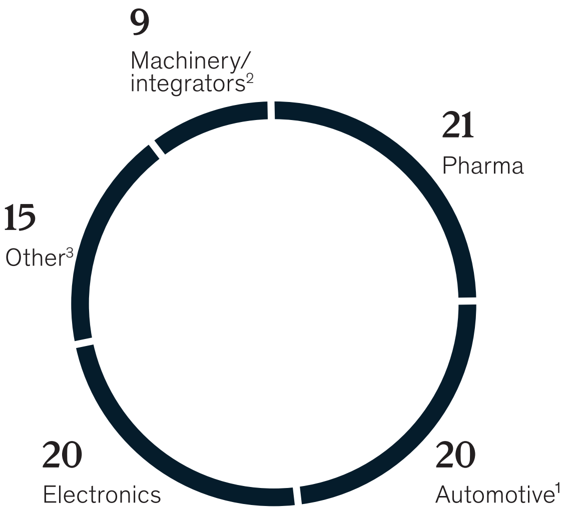
McKinsey's 2018 Global Robotics Survey solicited the perspectives of these two groups, and this chapter describes the insights derived from the survey's results. For a more detailed understanding of the survey and its participants, see Text box 1.

Text box 1

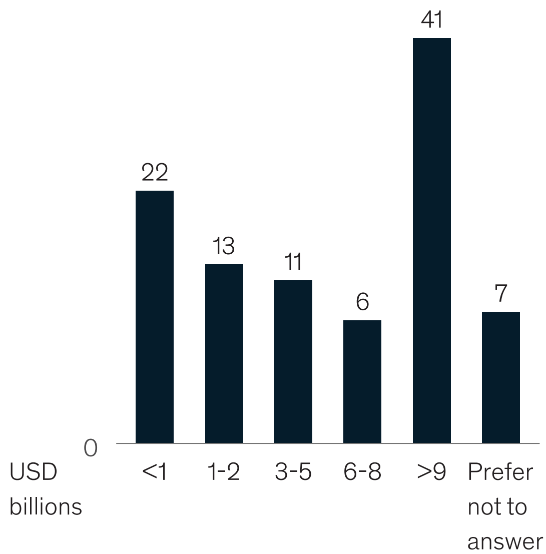
Key methodology aspects of McKinsey's 2018 Global Robotics Survey

The survey was an online survey of 85 OEMs and users globally and can be specified along the following dimensions:

Industries represented
Percent



Positions and organizations represented
Revenue



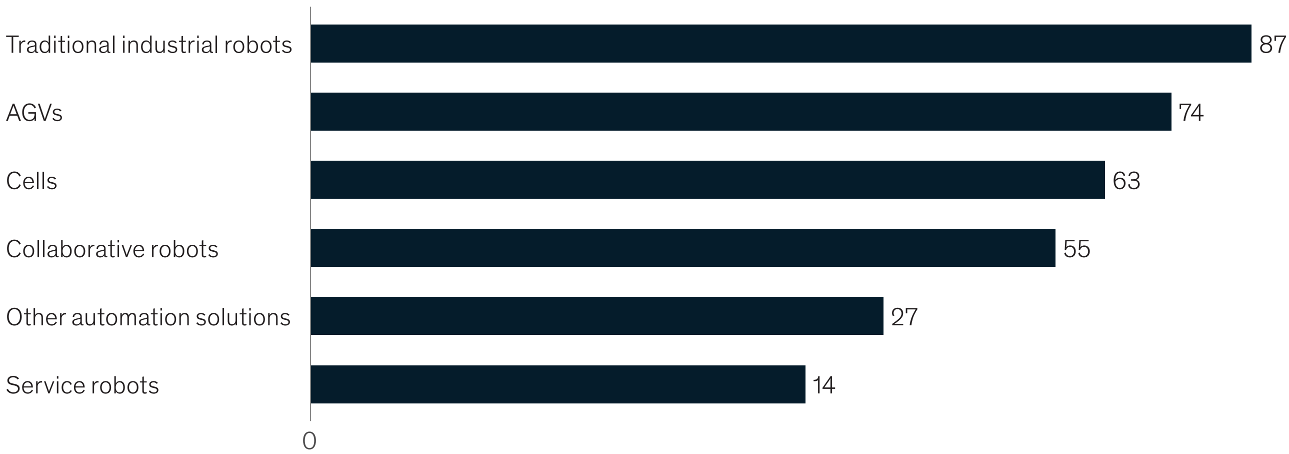
Industries represented are primarily in the automotive, consumer electronics, and pharma industries (including healthcare and chemicals)

Positions represented
Survey participants were heads of operations, manufacturing, supply chain, process engineering, and services as well as end users of robots, such as plant managers.

Organizations represented
More than half of the respondents represent companies with revenues up to USD 11 billion, and almost one third generate revenues of USD 40 billion or more. 32% of respondents' companies have more than 50,000 FTEs. Most either work at companies with 9 or fewer production sites or at companies with 40 or more production sites.

1 Automotive OEM, automotive supplier, commercial vehicles
2 General machinery, component suppliers, integrators (for robotics)
3 E.g., aerospace and defense, consumer goods
Source: McKinsey Global Robotics Survey 2018

Types of robots in installed base



The types of robots in the installed base of the survey respondents reflect a distribution similar to that of IFR-reported numbers, i.e., relatively high penetration of AGVs and cells compared to other types.

When looking through a sector-specific lens, electronics players seem to be the most sophisticated in terms of robotics adoption, as 100% of the respondents in this category indicate that they have traditional robots, AGVs, and cells in their installed base. Additionally, electronics players have a high installation rate of collaborative robots. In terms of robotics and automation applications, the results suggest that the most common ones are materials handling (including picking and packing, palletizing, and machine tending), assembly, and welding.

Growth expectations across industries

Investment expectations are high with 88% of respondents anticipating an increase in investment, which is in line with IFR market projections (see Exhibit 4). Respondents from the automotive industry indicate the highest expected investment in robotics and automation.

The investment increase across industries is mainly driven by the goal to decrease production cost. Investment is also motivated by the need for increased flexibility in production and improved capabilities of robots (see Exhibit 5).

88%

Exhibit 4

Investment outlook for robotics and automation industries

100% = 85 respondents

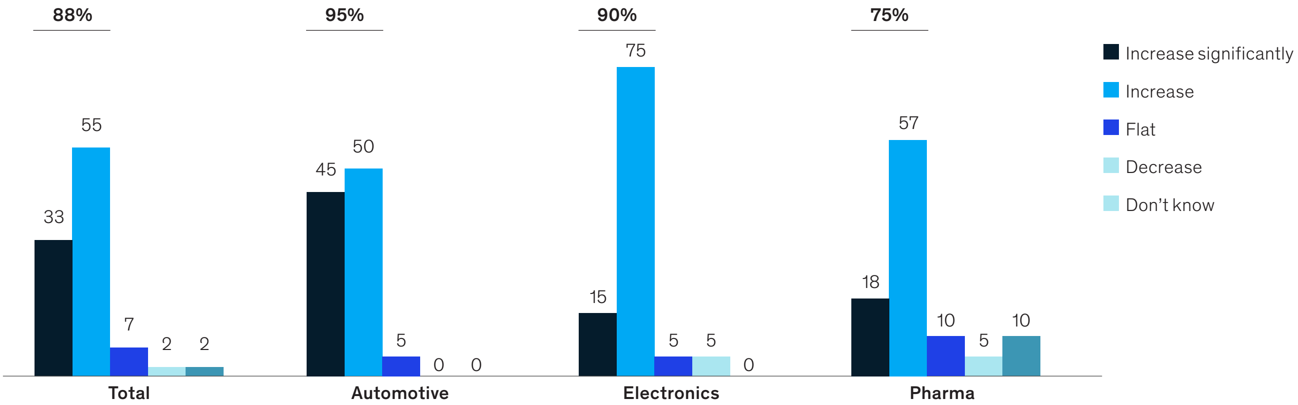
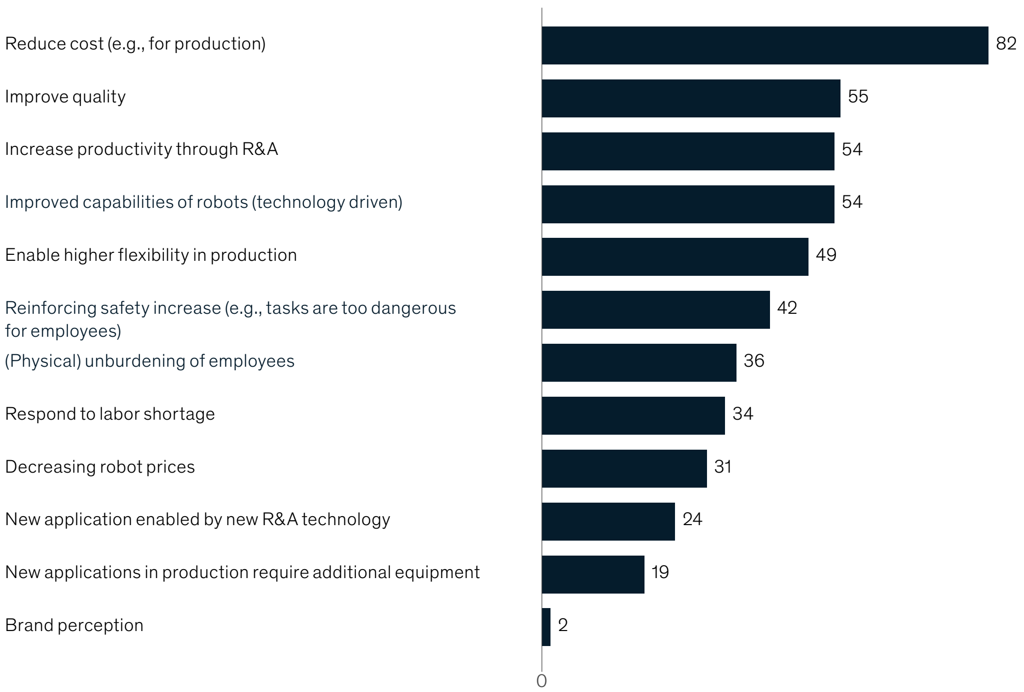


Exhibit 5

Main drivers triggering investment in robotics and automation solutions

100% = 85 respondents



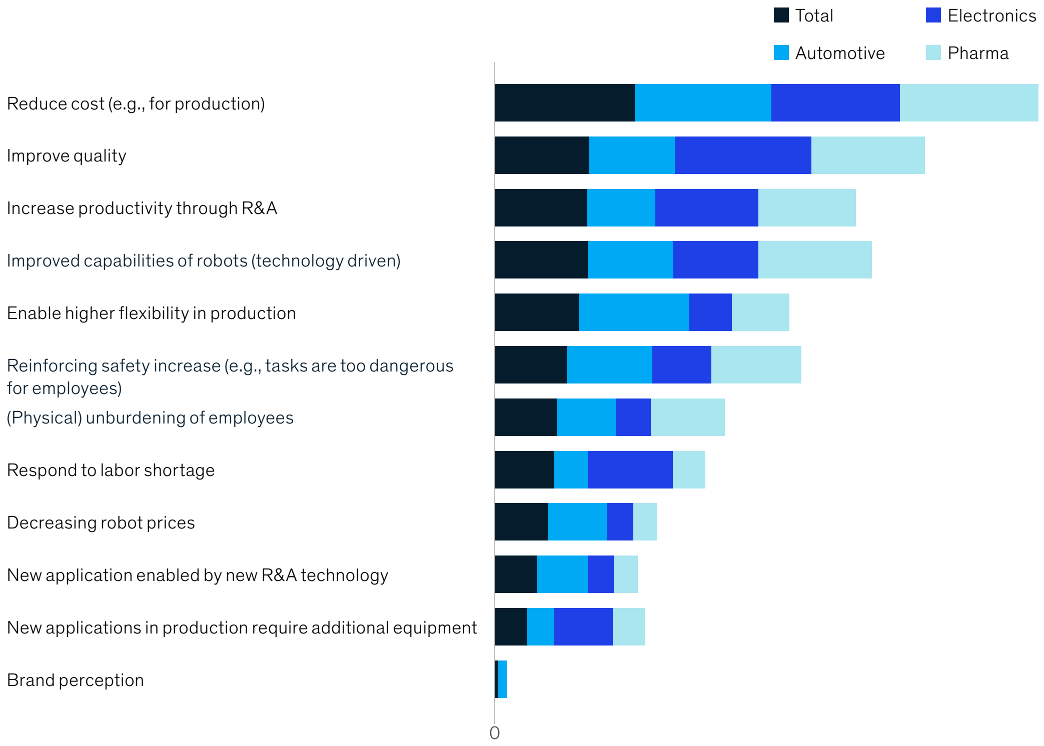
Source: McKinsey Global Robotics Survey 2018

While the investment outlook is very positive across the board, the relevant investment drivers differ by industry.

Exhibit 6

Investment focus by industry

100% = 85 respondents



Source: McKinsey Global Robotics Survey 2018

Perspective on growth drivers

Investment drivers

While the investment outlook is very positive across the board, the relevant investment drivers (beyond the goal of reducing production costs) seem to differ by industry (see Exhibit 6).

Automotive players invest for production flexibility

Our findings suggest that automotive manufacturers are seeking higher flexibility in the production processes as well as improved safety for employees from technology adoption. The cost of robotics technology is, however, the key driver for automotive players, even more so than for the other sectors. As for purchasing criteria (see also Exhibit 7), 67% of automotive respondents say that total cost of ownership (TCO) is a relevant criterion. The availability of integrators to work across geographies and applications is as relevant as performance for automotive players, with half of respondents from this industry saying that each criterion is relevant.

Electronics players invest for quality

The main drivers for the adoption of robotics and automation solutions in electronics are the needs for improved quality and increased productivity. Electronics players feel that robotics and automation can resolve labor shortages more so than in other industries. The requirement of additional equipment for new applications is also a driver of investment, i.e., when current machines do not have the capabilities to fulfill new needs. When it comes to the purchase decision, performance and TCO seem to be the two most important criteria, with 65% and 60% of respondents, respectively, designating them as relevant. The total cost of installation for application plays a role in the purchase, with 35% of respondents calling it a relevant factor in their decision making.

Pharma players invest for robotics capabilities
Pharmaceutical companies are investing as part of a strategy not just to improve quality in their production process but also employ robots with improved capabilities. Regarding purchasing criteria, 71% of pharma players say that overall performance (e.g., accuracy and speed) is relevant. TCO comes in second, with 57% of respondents in this industry naming it a relevant purchasing criterion. The cost of robots and safety requirements ranks equally, with 43% of respondents describing these criteria as relevant to the purchasing decision.

Investment-related challenges, roadblocks, and focuses

While the immediate investment drivers differ, the main challenges for all three industries are the same: cost of robots, lack of homogeneous programming platforms/interfaces, and lack of integrators working across OEMs/geographies/industries. For electronics and pharma, another important aspect is the lack of retrofit options/compatibility with existing equipment.

When we look at the roadblocks, the differences are more obvious. For automotive players, the main roadblock that needs to be addressed are contracts with the existing labor force. Often, automotive players and their productions are important employers in an area with long-standing commitments to their workforce. In these kinds of situations, it is a challenge to identify opportunities for how to apply new technologies. For both electronics and pharma, the respondents indicated that involvement of industry organizations (e.g., associations) could be helpful in addressing the roadblocks. This is the case for safety concerns.

Planned investment is very similar among the three sectors, with respondents across industries indicating that their most important investment focus by far will be on assembly, material handling, and picking and packing.

Purchasing criteria

Comparing the most relevant purchasing criteria revealed not only important similarities but also striking differences between the industries (see Exhibit 7). While overall performance (e.g., accuracy and speed) and TCO of the technology are the primary purchasing criteria, the former is considerably more important for players in the pharma industry (71%) and the electronics industry (65%) than in the automotive industry (50%).

What's more, the third most important purchasing criterion differs widely across the three focus industries:

— In the automotive space specifically, the availability of integrators to work across geographies and applications is a major purchasing criterion and even as relevant as performance.

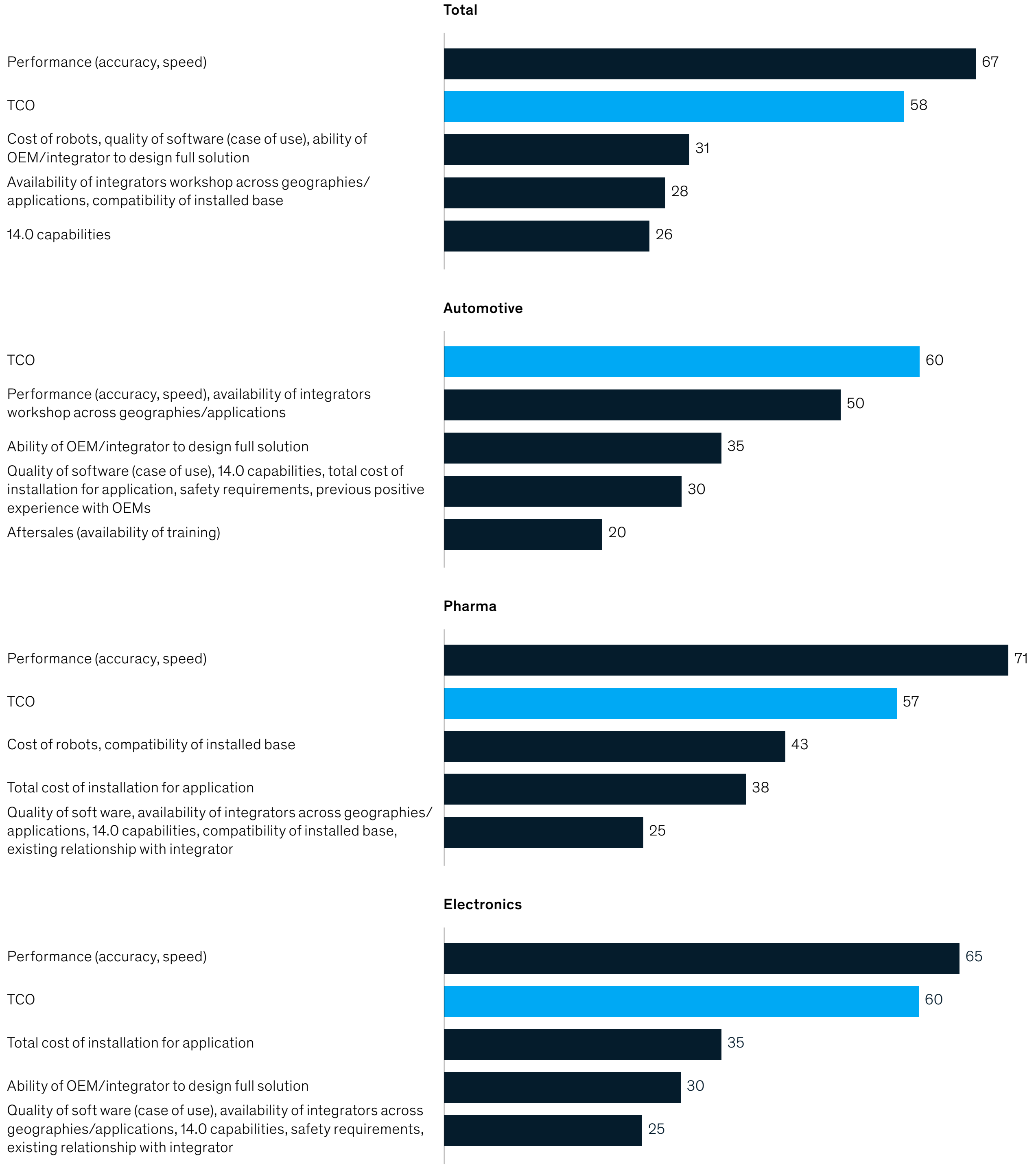
— For electronics players, the total cost of installation for application plays an important role in the purchase decision.

— In the pharma industry, the cost of robots and safety requirements rank equally as the number three criterion.

Exhibit 7

The most relevant purchasing criteria for respective organization

Percent



Roadblocks hindering growth

Survey respondents were also asked about the key challenges they are currently facing in implementing robotics. By far the most widely cited challenge is the cost of robots. Other key challenges include the lack of homogeneous programming platforms/interfaces, the lack of integrators working across OEMs/geographies/industries, the general lack of experience working with automation, limited retrofitting options, as well as the general lack of suitable robotics and automation solutions (see Exhibit 8).

When considering challenges on an end-user industry basis, a few themes emerged:

— Automotive players identify the cost of robots as the primary challenge to adoption. They also experience a lack of availability of fitting robotics or automated solutions into current workflows.

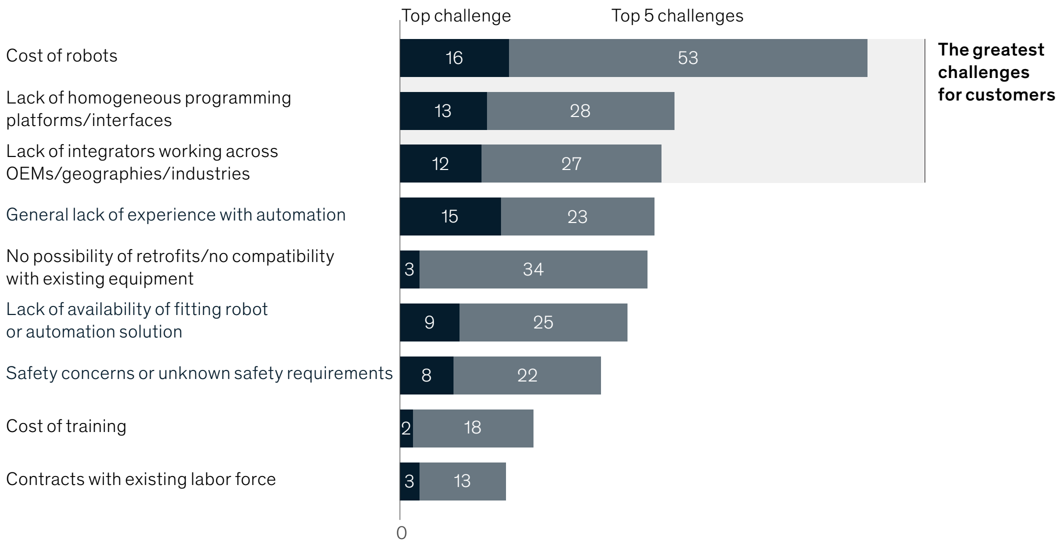
— Electronics players share the need for lower costs but also highlight the lack of backward compatibility/retrofitting as a primary challenge.

— Pharma companies are very similar to their electronics counterparts in their need for lower costs and better backward compatibility.

Exhibit 8

Customers indicating top challenge and top 5 challenges

Percent



Source: McKinsey Global Robotics Survey 2018

The respondents' comments provide insights into potential solutions to these challenges that can be summarized in three categories:

Simpler to apply
Regarding the lack of homogeneous programming platforms/interfaces, respondents seek to establish a common platform for programming and common interfaces to make it easier to program and teach robots new tasks.

Simpler to connect
Regarding the lack of integrators working across OEMs/geographies/industries, respondents mentioned the following as solutions: improved integration capabilities of robots within existing solutions; readiness of system integrators to install a true turnkey solution for large industrial automation in a short time span; and more candor and transparency among OEMs regarding who the better system integrators are. Given the fact that many OEMs also act as system integrators, the last point seems difficult to address.

Simpler to run
Other challenges include the lack of fitting robot or automation solutions as well as the lack of retrofit solutions or solutions compatible with existing equipment.

All players identified the cost of robots as one of the primary challenges to adoption

Unleashing the robotics industry’s full growth potential

Three levers can be used to both remove the obstacles hampering the projected 14% annual growth of industrial robotics between 2019 and 2021 and unlock the industry’s additional growth potential.

Based on findings from recent McKinsey research – particularly the challenges uncovered by the survey (see Chapter 2.3) and an aspirational “wish list” provided by end users – we have derived a set of considerations for OEMs and system integrators. Specifically, three levers can be used to both remove the obstacles hampering the projected 14%[13] annual growth of industrial robotics between 2019 and 2021 and unlock the industry’s additional growth potential.

Developing standards for interoperability

While robotics costs are declining, the price of robots remains high, setting the bar high for ROI. Established players have split the market for industrial robots among themselves. The customers with the largest buying power (e.g., automotive OEMs) are typically those ordering whole production lines with robots from the same manufacturer and using them for an extended period of time. Limited standardization drives

13 Source: IFR

high prices for cells and solutions. Basically, each robotics OEM has its own standard. In addition, certain robotics parts are scarce (e.g., drivetrains), and this restricts growth.

Some OEMs have tried to lower production costs by setting up production in low-cost countries (e.g., China) but with only limited effect so far. However, new players are entering the market in the manufacture of specific robots (e.g., collaborative robots), and new offerings are being introduced (e.g., plug-and-play cell solutions that can be set up faster and at lower cost). But so far, there is no low-/lower-cost provider that has managed to disrupt the market.

From our point of view, product modularization and the standardization of accessories and auxiliary equipment would be beneficial for all stakeholders. Higher standardization would facilitate the use of robots from different manufacturers for end users. The end users in our survey complain about the difficulty in programming, the lack of a universal platform for robotics, and the lack of a common platform for programming and interfaces. Addressing these challenges could unlock additional potential for OEMs. So far, however, efforts to drive a common platform for programming and interfaces with regard to the IoT, for example, have been limited. In general, system integrators would profit from a common platform, as it would allow greater flexibility in integrating robots and cells from different OEMs. Such a productivity boost would increase unit sales and thus positively affect OEMs.

Promoting robotics-related upskilling and retraining at scale

Unlocking the industry's additional growth potential requires, among other things, that companies that would be willing to invest in robotics and automation over and above the currently signaled level have the prospect of finding the talent needed to install and operate these machines. However, while talent with robotics-related capabilities is already a rather scarce resource, its scarcity will increase soon, fast, and significantly due to the projected dynamic rise of automation and robotics. A recent MGI study,[14] for example, assumes that the total number of jobs related to developing and deploying new technologies, i.e., automation-, IT-/AI-, and robotics-related applications, may grow to 20 to 50 million globally by 2030 – and that as many as 375 million workers globally will have to master fresh skills as their current jobs evolve alongside the rise of automation, robotics, AI, and the capable machines thereby enabled.

In view of this, robotics OEMs and system integrators should seek to work – in concert with other stakeholders – towards raising end users' (companies') awareness of the scope of both the short-term and medium-term talent shortages as well as supporting the launch of appropriate measures to resolve them.

[14] McKinsey Global Institute, "Jobs lost, jobs gained: workforce transitions in a time of automation," December 2017; https://www.mckinsey.com/~/media/McKinsey/Featured%20Insights/Future%20of%20Organizations/What%20the%20future%20of%20work%20will%20mean%20for%20jobs%20skills%20and%20wages/MGI-Jobs-Lost-Jobs-Gained-Report-December-6-2017.ashx

As for mitigating the imminent talent scarcity, the starting position is not all that bad as the findings of a previously published McKinsey article indicate: many companies' executives seem to be aware that they need to upskill a significant share of their workforce between now and 2023 due to advancing automation and digitization, and upskilling of the current workforce is frequently even considered "a license for operating in the future."[15] Robotics OEMs and system integrators should thus focus their promotion activities (in this context) on supporting end users' companies, which will have to invest intensively in, above all, upskilling existing workers by developing effective and tailored upskilling programs.

When it comes to bridging the medium-term skill gap, more ambitious efforts are required. First of all, this has to do with the fact that – due to the 2030 talent shortage's greater complexity and its seemingly lesser urgency – it is much more challenging to raise an appropriate awareness of it and build sufficient momentum for action towards solving the challenge. The latter challenge is further increased by two aspects:

Additional major stakeholders need to be involved

The responsibility to manage this "large-scale shift in capabilities" lies both with the companies regarding reskilling their existing workforce and with government bodies defining education plans (e.g., for universities with both academic and vocational training).

Decreasing funding and support from governments

While public spending on labor force training and support has fallen steadily for years in most member countries of the Organisation for Economic Co-operation and Development (OECD), the task of retraining current workforces and qualifying the next generation of workers will become significantly larger and more complex. According to the findings of a recent MGI study, many countries might need to undertake "initiatives on the scale of the Marshall plan" to this end.

Robotics OEMs and system integrators should thus focus their promotion activities on convincing companies, governments, and societies at large of the fact that robotics-related (re) training at scale is critical – for individual workers, companies, and national economies alike – to creating value and ensuring competitiveness in the future.

Many executives seem to be aware that they need to upskill a significant share of their workforce between now and 2023 due to advancing automation and digitization

15 "62% of the executives said they believe they will need to retrain or replace more than a quarter of their workforce between now and 2023 due to advancing automation and digitization"; see: McKinsey article "Retraining and reskilling workers in the age of automation," January 2018; https://www.mckinsey.com/~/media/McKinsey/Featured%20Insights/Future%20of%20Organizations/Retraining%20and%20reskilling%20workers%20in%20the%20age%20of%20automation/Retraining-and-reskilling-workers-in-the-age-of-automation.ashx

Bringing robotics to small and medium-sized companies

Until recently, small and medium-sized companies were relatively unattractive end-user customers for most robotics OEMs and system integrators – above all due to the relatively small revenues they generated and the need to nevertheless develop (highly) customer-specific solutions for them in many cases. In view of the recent progress made in robotics technology, however, we believe that it makes perfect sense to consider this pool of companies a rather promising new customer segment that should be targeted and served.

Yet to successfully tap into this growth potential and generate additional as well as high-margin revenues with small and medium-sized companies, robotics OEMs and system integrators should take the following three concrete actions:

Innovate their product offer and promote its advantages

Primarily because of the resulting positive effects for price and margin development, OEMs should noticeably increase both their level of product standardization and the number of turnkey solutions that they offer especially for small and medium-sized companies. Additionally, to promote their new product offering and provide convincing proof of their qualities and performance, they should showcase these turnkey solutions, e.g., through cooperations with industry organizations.

Educate about the benefits from investments in new-generation robots
Especially robots' formerly high prices/costs as well as the relatively limited and static application possibilities used to make achieving a positive return on invested capital a barrier. Thus, for a long time investments in robots were, in many cases, not very gainful for small and medium-sized companies. In the wake of new technological and predictable price/cost developments, however, this will change. Now, a health and safety, quality, cost-savings, and/or productivity justification – and in some cases a combination of all four – for robotics investments even in smaller companies is expected. In this context, three advantages of the new generation of robots should be taken into account:

— **Health and safety improvements in the work place.** By removing the human resources from dull, dirty, and dangerous work, robots can help to improve health and safety in production.

— **Significant productivity and production quality increases.** Robotics-based automation can take unwanted variation out of a production process or system, thus resulting in improved production quality. In addition, by facilitating the use of the AI capability, the process parameters of productivity and quality can be further enhanced.

— **Inexpensive reteach**. The new generation of robots is more flexible. Especially for smaller companies, investing in robotics is more attractive due to the greater number of usage options for a specific robot this flexibility affords.

Inform about measures for addressing the key challenges relating to robotics investments
In general, high robotics prices/costs, shortages of skilled workers, and negative workforce-related perception of robotics are bigger investment barriers for smaller companies than they are for large companies. OEMs and system integrators should thus develop a communication plan tailored to this new target group that clearly outlines what they and their industry are doing to effectively reduce prices, mitigate skills shortages, and participate in the workforce-related public.

Outlook

The use of robots is growing due to technological advances that support an increase in the number of applications. There are now robots for most applications from materials handling to assembly. In addition, there has been an improvement in sensors, such as tactile and vision systems, that increases the set of applications for robots and makes them simpler to implement. There has also been an increase in computing power, giving robots AI capabilities.

Against this backdrop and at this stage of development, OEMs and system integrators should investigate how they can facilitate more adoption, more value, and further growth by (providing solutions for) bringing additional simplicity in three areas:

Simpler to apply

Potential end users will be increasingly likely to envision use cases for robots as the choice of robots and the talent with the requisite skill set to bring the robots online becomes more available. Simulation software can further close the gap between conceivability and installation by helping end users prove their design before committing to the final investment.

Simpler to connect

Readily available industrial connections, simpler integration of end effector, systems I/O, and communication can make robotics easier to implement within existing structures.

Simpler to run

Interactive or interconnected interfaces put even complex programming tasks in the hands of frontline operations, making factories less dependent on expert suppliers and engineering departments.

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